pallida.—Burma, Thoungyeen, March, 1862. (Dr. Brandis).—This species will range along with *A. ochraceum*, Dalz.

LYCOPODIACEÆ.

108. Selaginella semicordatum, J. Scott, (in Journal of Agri-Horticult. Society of India. New Ser., vol. I, part 2, p. 261 (1860) is *S. semicordata*, Spring, Enum. *Lycopod.* No. 78 and Monogr. *Lycopod.*, II, 107 (*Lycopod.* Wall. Cat. 137).

S. implexa, J. Scott, l. c. p. 262, is identical with *S. tenera*, Spring, Enum. *Lycop.* No. 144 and Monogr. *Lycopod.*, II, 241.

S. aristatum, J. Scott, l. c. 262, founded apparently upon *Lycop. aristatum*, Roxb., in Maclell., Calcutt. Journal. Nat. Hist., IV, 473, is unknown to me, and it is impossible to compare the plant with any of Spring's diagnoses, Mr. Scott's description being insufficient in several points.

LEMNACEÆ.

109. **Lemna tenera,** n. sp.

Frondiculæ cruciatæ, lanceolatæ ad lineari-lanceolatæ, sæpius subcurvulæ, acuminatæ, basi magis minusve rotundatæ, membranaceæ, subtus (in viro) obsolete trinerves et reticulato-venosæ; radiculæ solitariæ.—Frondiculæ 3—4 lin. longæ, basi lineam circiter latæ ; radiculæ vix pollicares.

Pegu, in jungle-swamps of Pazwoon doung valley, rare.

Arrangement for the discharge of long Overland Telegraph lines, *by* Louis Schwendler, Esq.

[Received 27th January, 1871.]

When organizing more regular and instantaneous telegraphic communication between the Presidency towns of India, and especially between Calcutta and Kurrachee, it was observed that discharges occurred sufficiently strong to affect the relay of the sending station, and giving rise to the so called "return beats." These discharges* through the relay of the sending station are

* It is well known that an overland telegraph line acts as a Leyden jar in the same manner as a submarine cable, having, however, only a much smaller capacity on account of the insulating layer (the air between the telegraph wire and surrounding conductors) being very thick. But, though the capacity

inconvenient for many reasons, the most important of which is, that they are frequently stronger than the signalling current of a far distant station, and consequently throw the relay out of its adjustment, and so make it unfit to receive a calling signal from such a station. It was, therefore, necessary to devise some simple means by which these discharge currents could be safely eliminated from the relay of the sending station,* and it was found that for terminal stations a peculiarly constructed key answered the purpose best. This key, after each signal sent, by a proper application of well tempered springs, makes a momentary contact direct with earth, by which the discharge of the line is effected before the final contact with earth through the relay is made, and such keys were supplied to the terminal stations of the Indian main lines, where they have worked well. But to eliminate the discharge currents from the relays of terminal stations is of far less importance, than to do so from the relays at translation stations; for it is clear that the discharges in translation stations may not only be inconvenient, but may momentarily interrupt the line, so that the real signal cannot pass on; and even if they do not cause interruption during the whole of a signal, they will, at all

may be small in comparison with that of any cable, it is evident that a long, well insulated overland line may shew nevertheless very decided charges and discharges. Fortunately the charges of the Indian Main lines, (so long in comparison with the direct worked lines in Europe), still occupy such a short time as not to influence in the least our maximum working speed attainable with the present signalling system (25 to 30 words a minute), *i. e.* a signal sent from Calcutta to Agra arrives there practically at the very moment it is sent. The discharges, however, affect most seriously our instruments, and it is, therefore, only this effect that is treated of in the present paper.

* The method of a station permanently cutting out its own relay while sending has never been adopted in this country, and I believe also never will be, for however perfect lines and instruments, and accomplished employés may be, or may become, it is always highly desirable that a receiving station should be able to call in the sending station at any moment during the transmission of a message.

In India we invariably use positive currents, (or copper to line), for signalling, because they reduce the leakage. By using positive currents for signalling in one direction and negative currents in the other, and having polarized receiving instruments, the effect of discharges would be of course so far eliminated that the receiving instruments would not actually be worked by them, the discharges going in the wrong direction through the polarized relays. But this is a bad plan. The continued passage of strong discharges through a polarised relay make it, on account of remanent magnetism, unsensitive, and consequently a continual and most tedious adjustment of the receiving relay would be necessitated; this again would produce great irregularity in the working of the lines.

events, produce points instead of bars at the receiving station, thereby causing considerable delay and confusion.

It is true that in principle the arrangement in use at terminal stations might also be applied at translation stations, where the armatures of the sounders, or any other receiving instruments, act as keys; but there are many mechanical difficulties in the way, especially the very small play of these armatures which would make such a method unsafe. It was, therefore, decided to use for translation stations another discharging arrangement, which I will now describe. This arrangement consists of a Siemens' polarized relay with comparatively small resistance, and of a small bobbin of wire acting as a shunt to the coils of the relay, which latter may appropriately be called the "Discharging relay." The parallel circuit of discharging relay and bobbin of wire is interposed between the line to be discharged after each signal and the sending battery.

The contact screw of the discharging relay is connected with one end of the receiving relay, while the axis of the tongue of the discharging relay is in connection with the other end of the receiving relay, *i. e.* the earth. Such an arrangement may be of course applied equally well for terminal stations in place of a discharging key, and as the telegraph circuit for two terminal stations is of a simpler nature than the translation circuit, it will be clearer to explain the action of this discharging arrangement for two terminal stations working direct with each other, as for instance, Calcutta and Agra.

The following diagram (Fig. 1) will give all the necessary connections.

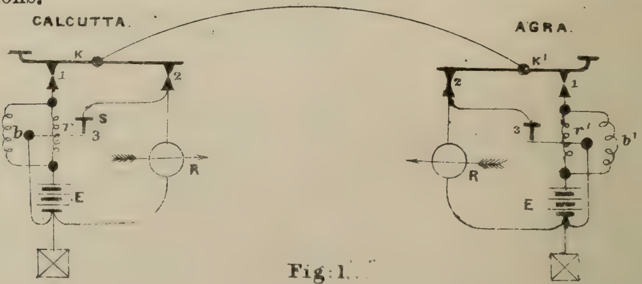


Fig: 1.

R and R′ are the receiving relays, the tongues of which, when a current is sent, close the circuit of a local battery, containing the receiving instrument in the usual manner.

K and K′ are two common telegraph keys, r and r' the two discharging relays, b and b' the two bobbins of wire acting as shunts to r and r' respectively.

Suppose Calcutta sends a signal to Agra by pressing the key K on its front contact 1, then a part of the Calcutta signalling current passes through r, and if strong enough, attracts the relay tongue, pressing it against the contact screw S, and as long as contact 1 lasts, contact 3 will exist. But as soon as the signal is completed, *i. e.* when the key leaves contact 1 and makes contact 2, all the discharge of the long line would pass through the receiving relay R, if contact 3 ceased just before contact 2 were re-established. This is, however, not the case, because by the application of the shunt b, in virtue of which an extra current can form itself through the coils of the discharging relay, contact 3 is sufficiently prolonged to exist for a moment simultaneously with contact 2, consequently the whole discharge, or at least the greatest part of it, has time to pass through contact 3 direct to earth, instead of going through the receiving relay R. The same process will of course repeat itself at each signal sent, and will also be the case when Agra is sending instead of Calcutta.

Such an arrangement answers the purpose perfectly at Agra on the great and important main line between Calcutta—Kurrachee, where it has been in use (in translation) for some time.

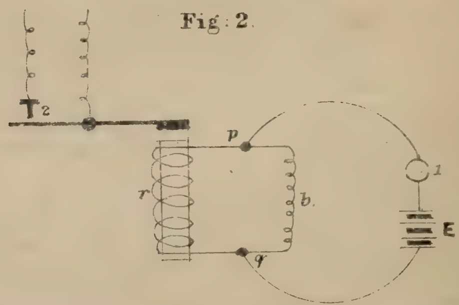
It may be mentioned here that it does not at all interfere with the maximum working speed, attainable with our present system of signalling, namely 25—30 words a minute.

The very great prolonging power of such a shunt not having been known at first, it was thought necessary to assist the prolonging effect by a fine spring of very small play, fixed to the tongue of the *discharging relay.* But such a spring is not wanted, and it is much better to dispense with it, because, however small the play of this contact spring may be made, it will always in some measure lessen the sensitive adjustment of the discharging relay.

As it was evident that the prolonging effect of the shunt must greatly depend upon its resistance, (supposing the resistance of the discharging relay and also all other circumstances were given), the following investigation was made in order to ascertain its amount.

Figure 2 represents the simple circuit as obtained from diagram 1.

Fig: 2.



Two bobbins of wire, r and b, are connected parallel to the two poles of a battery E, the circuit of which may be closed and opened at will by a stopper, 1. Only one of the bobbins, r for instance, contains iron, which becomes a magnet as soon as the battery circuit is closed. When the circuit is opened, the magnetism in r ceases, causing an extra current in $(r + b)$ which acts in the same direction as the original battery current, and consequently causes the loss of magnetism in r to go on much slower, than it would without such a shunt b; and therefore, if the magnetism in r were made use of for closing a contact 2, this contact would be somewhat prolonged by such a shunt. Consequently the question to be solved is, what must be the resistance of this shunt, supposing r, and everything else were given, in order to make the remanent magnetism a maximum, *i. e.* the prolonging effect of the shunt as regards contact 2 greatest.

That for a given r a certain b does exist for which the extra current, or its equivalent the remanent magnetism, is greatest, follows simply enough. Suppose for instance the resistance of the shunt b were infinite, which is the same as having no shunt at all, then no extra current would exist, though its cause, *i. e.* the magnetism produced in r by closing the battery circuit, would be greatest. On the other hand, if the resistance of the shunt b were taken as infinitely small, then, (though there would be the best possible channel for an extra current), no such current could be established, because no original current would pass through r, and therefore no magnetism in r could have been developed. Knowing, therefore, that for $b = \infty$ and for $b = o$ the extra current is $= 0$, it follows that there must be one or more values of b between these limits, for which the extra current is a maximum.

However, the function, by which this extra current, or better the remanent magnetism in r, is expressed, is of such a nature, that it has only *one* maximum, and this can easily be calculated, since all the laws determining it are perfectly known.

In diagram 2 we will designate by r the resistance of the bobbin producing the magnetism (which in the discharging arrangement represents the resistance of the coils of the discharging relay); and for brevity we may suppose that the whole resistance between the points p and q through r is used for producing magnetism.

Suppose also—

n the number of convolutions in r;

x the resistance of the bobbin acting as a shunt to r, and extending between p and q;

E the electromotive force producing the original current;

l the resistance between the points p and q through the battery E, including the resistance of the battery;

thus the current C which passes through r, when 1 is closed is—

$$C = E \frac{x}{l\,(r + x) + r\,x},$$

and consequently the magnetism m, developed in r by C is:

$$m = C\,n = E \frac{n\,x}{l\,(r + x) + r\,x},$$

and, supposing the conductivity of the wire, filling the given space of bobbin r, constant for any diameter whatever, and neglecting the thickness of the necessary insulating covering of the wire in comparsion with its diameter, we may substitute for n the value $n =$ Constant $\sqrt{r}$.

Thus we have—

$$m = \text{E Const}\,\frac{x\sqrt{r}}{l\,(r + x) + r\,x}.$$

The ceasing of this magnetism, after the battery circuit has been instantaneously opened at 1, must be considered as the cause for producing an extra current in the closed circuit $(r + x)$, which extra current in its turn reproduces magnetism in the iron bar in the coil r. This whole process of course occupies time, however short it may be and goes on steadily. But it will lead apparently to the same result for our purpose, if we suppose that the cessation of the original magnetism produces instantaneously the whole extra current, and that the extra current, (or better an average value of it, since it is variable as regards time), is used for producing fresh magnetism in the iron bar of the coil r. Under these circumstances it is reasonable to take a proportional quantity of the original magnetism as the new electromotive force for producing the extra current C′ in the circuit with the resistance $r + x$.

Therefore we have

$$C' = \text{E Const}\,\frac{x\sqrt{r}}{\left\{ l\,(r + x) + r\,x \right\}(r + x)},$$

and this expression multiplied by the number of convolutions, n, gives us the remanent magnetism m', or as $n = \text{Const}\ \sqrt{r}$,

$$m' = \text{E Const}\,\frac{x\,r}{\left\{ l\,(r + x) + r\,x \right\}(r + x)} \quad \ldots\ldots\ldots \text{(I)}$$

Now it is evident that the prolonging effect, *i. e.* the time during which the bar of iron keeps perceptibly magnetized after the instantaneous opening of the battery circuit, must increase with m', and consequently by making m' a maximum, the prolonging effect of the arrangement must also be greatest. Taking, therefore, in the above expression for m', x only as varriable, we get in the usual way

$$* \quad x = r\sqrt{\frac{l}{l + r}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(II)}$$

corresponding to the maximum of m.

* We have—

$$\frac{dm}{dx} = \frac{l\,r^2 - x^2\,(l + r)}{N^2},$$

In the application to a long overland line, l represents the line resistance including the resistance of the sending battery and distant receiving relay, while r is the resistance of the coils of the discharging relay.

In order to weaken as little as possible the signalling current by the introduction of such a discharging relay, we take naturally r, its resistance, only so great, that a given electromotive force, (as is generally used for signalling through the line), will work it with safety through the given line resistance, and if the discharging relay is of a good construction, this r can always be neglected in comparison with l.

Therefore we have from formula (II)

$$x = r.$$

Or to make the prolonging effect of the shunt a maximum, its resistance must be equal to the resistance of the coils of the discharging relay. This law will hold good for any long overland Telegraph line,

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where $N = \left\{ l\,(r + x) + r\,x \right\} \left\{ r + x \right\}$

$$\therefore \frac{d^2m}{dx^2} = -\frac{2\,x\,(l + r)}{N^2} - \frac{2}{N} \cdot \frac{dm}{dx} \cdot \frac{dN}{dx}$$

$\therefore$ when $\dfrac{dm}{dx} = 0$

$$x = r\sqrt{\frac{l}{l + r}}$$

and $\dfrac{d^2m}{dx^2} = -\dfrac{2x(l + r)}{N^2}$

which is always negative for a positive value of x.

The function m' (formula I) is to be considered as representing the remanent magnetism in the closed circuit $(r + x)$, no matter by which of the two coils the magnetism is produced; thus m' must necessarily be symmetrical as regards r and x. But having selected one of the two coils by which m', the remanent magnetism, *is* to be produced, it is at once fixed which of the two coils must be taken as variable in order to find the maximum of m'. If, for instance, r is taken as the coil developing m', while x acts as shunt only, neither producing extra current nor magnetism, then the shunt x must be taken as variable and not r, since otherwise factor $\dfrac{r}{\left\{ l\,(r + x) + r\,x \right\} \left\{ r + x \right\}}$ would have to be differentiated, giving that value of r which represents a maximum of m', developed by x; just the case to be avoided as much as possible.

and it is only for a long line that such a discharging arrangement is required.

As regards the absolute value of r, it was found that 200 S. U, using a Siemens' polarized relay, were quite large enough. Such a relay works safely with 30 Minotti's cells through 10,000 S. U.

The shunt itself, even without having iron in it, produces an extra current which is in the same direction in the shunt, as the primary current, and consequently opposes the extra current produced by the coil r in the closed circuit $(r + x)$.

In order to have, therefore, the action of the coil r not too much lessened by the extra current, produced by the shunt, it is necessary to make the latter of the thinnest possible German silver wire, and wind it on a large bobbin with the convolutions as far distant from one another as possible. Another method would be to wind the bobbin bifilarly.

In conclusion I may mention that the longest main line in India is the one between Calcutta and Kurrachee 1,700 miles in length which has been worked direct now for more than two years,—Agra (which is about at the middle) only in translation. During the dry season, when the lines up-country often have an insulation of more than 200 millions S. U. per mile, it is possible to work this enormous distance altogether direct without Agra in translation; but practically nothing would be gained by this, since then on account of the great length the charge becomes so large as to reduce the speed to less than 15 words a minute, while by having Agra in translation the speed, if only the signalling system would allow of it, would reach to upwards of 60 words a minute.

(*Note*,) Mr. A Cappel, in his report on the Central London Office of the Electric and International Telegraph Company, states that a shunt in connection with an electro-magnet for discharging one of the cables was made use of as early as 1867, and was pronounced to him by Mr. Culley as an invention of one of the Telegraph clerks This appears to be the first application of the extra current for this purpose, but I am not aware whether this simple principle has since been used for overland telegraph lines.

Mr. Cappel says—

"The duration of the zinc current, (necessary to neutralize, after each signal sent, the positive discharge of the cable), can be regulated by varying the resistance of the shunt, but no definite law or conclusion has yet been arrived at on the subject."